Keio University

Thesis Abstract

No.

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Title of Thesis: Integrating Remote Sensing Images and Public Administrative Data for Monitoring Deforestation of Tropical Peatland.

Summary of Thesis:

A comprehensive tropical peatland monitoring is a crucial factor for the preservation of tropical peatland in Indonesia. However, existing approaches in the tropical peatland monitoring much emphasized on biophysical aspects while neglecting human factors of the deforestation. Therefore, this research is aimed at developing an integrative method for monitoring tropical peatland deforestation in which biophysical aspects and human-socio factors are both assessed. Remote Sensing (RS) Images and Public Administrative Data (PAD) are used as data sources. However, challenges exist in both RS analysis and PAD analysis. As a tool for biophysical assessment, current RS techniques for monitoring artificial waterways (AW), human made structures such as canals and ditches, are less studied, particularly for traditionally built canals which usually very small in size. Pixel-based RS may not really appropriate to do so. A Geographic Object-Based Image Analysis (GEOBIA) is more appropriate. Meanwhile, for monitoring human factors of deforestation, PAD analysis requires appropriate base maps as a geocoding tool to spatially analyse the data. Therefore, this study develop a framework in which biophysical aspects and human factors are assessed simultaneously for a comprehensive tropical peatland monitoring. Land cover change and AW development are target of the assessment. They are indicators of human interference to the tropical peatland. For land cover changes, assessment is conducted using supervised classification with Landsat images as the main data source. Meanwhile, for AW detection, integration of local knowledge and image processing is applied in a GEOBIA approach of RS analysis. Further, in order to understand human factor behind the AW developement, the result of detection is integrated with PAD using RT (Rukun Teetangga/Neighborhood Associaation) as spatial key. For the prupose, RT Base Map (RTBM) is developed using village sketch maps of population census. However, typical sketch maps problems including distortion, schematization, and incompleteness add more challenges to the boundary uncertainty issue in the development of RTBM. To solve the issues, RT is plotted from the sketch map. In order to make it possible to play as a linker for geocoding though uncertain in the boundary, the RT is seperated as point (landmark, centroid), line (rivers, roads), area (boundary) before georegistered as a new base map. Further, a data model is developed to build the RTBM before using it as geodocing tool. After an accuracy assessment, it was found that the procedure can improve the base map accuracy from 49 percent as of direct digitization to be 75 percent. As a case study, this research scrutinized Sebubus Forest in West Kalimantan Province, Indonesia.

Landsat image classification shows that around 80% of total 14.501 Ha of Sebubus Forest was still covered by forest in 1995, during which data from local government indicates it was relatively free from AW. Rapid increase of deforestation found in 2009 and 2013 in which the bare land reached 22.5 percent and 35 percent respectively. In consequence, by 2016, only 11.56 % of total area remained forest. Furthermore, using new

GEOBIA technique, 22 new canal systems were detected in 2009, mostly in villages of the western side of the forest. On average, there have been 20.81 km or 8 new AW systems developed in Sebubus Forest every year from 2009 until mid of 2017. In 2014, primary canals went across the peat dome area. As of 2015, the primary canals were completely crossing the forest from the west to the east. In 2017, the AW's networks have totally covered the forest. On the other hand, using GIS advantages, PAD analysis shows that the geographical patterns of land cover changes and AWs development were in line with the patterns of population distribution and demographic attributes. In 2005, some activities slowly infiltrated into the forest. By 2009, huge deforestation detected on the northern edge of the forest in which bare land increased from 179 Ha to be 3.267 Ha. The significant increase was mostly related to 3 villages in Jawai Sub District named Sarang Burung Danau, Sei Nilam, and Sarang Burung Kolam. From the villages, PAD analysis found that, the centroids of RT boundary disperse evenly and line up towards the forest from the west. In contrary, RT centroids tends to be clustered in villages of eastern side. Poor people were found between 72-129 people in RTs proximate to the deforested area compared to only 10-43 people in distant RTs. Another data shows that from 11 villages in the western part where high rate of deforestation happened, number of poor household were found between 130 until 325 families per village, much higher than 25 to 129 in 10 villages of less deforested side of the forest. From land tax databases, it was found that number of land tax registration in RTs of western side was very few in 1999 compared to more than 300 per RT in villages of eastern part. However, the number rose sharply in 2011 when land tax registration in RTs of villages of western side was 14-345 per RT.

Highlight by chapter:

Chapter 1 introduces the research step by step. In this chapter, the current situation of tropical peatland as well as problems related to the conservation of tropical peatland in Indonesia is presented. Technical problems related to the tropical peatland monitoring are discussed. Objectives of research and hypothesized solutions for achieving them are also discussed. Moreover, original parts of the research and its contribution both scientifically and practically are underlined.

Chapter 2 reviews related literature structuring the theoretical basis for this research. The discussion highlights three components; first, fundamental concepts and theoretical background for a deep discussion on tropical peatland; second, contemporary literature of remote sensing techniques and its application in the tropical peatland monitoring; an third, the concepts of PAD, issues related to it, and key aspects for the employment of the data for this research.

Chapter 3 discuses proposed framework for an integrative approach in the tropical monitoring. Each components are discussed in sections. General overview of the framework and logical background of the whole model is presented in the section 3.1. In the section 3.2, flow and components of the proposed model are presented. Meanwhile, in the section 3.3 and the section 3.4, RS analysis as one of the main components in the model is discussed. Two RS approaches used in the model are presented one by one. Finally, in the section 3.5 and the section 3.6, PAD is presented. Firstly, method for the development of RTBM is highlighted. Then, model for linking PAD with the RTBM is presented.

Chapter 4 presents the implementation of RS components of the model. Land cover analysis is firstly

presented. In this analysis, all available images from the Landsat's archives were downloaded and selected based on predetermined criteria. Then, NDVI analysis were conducted to the selected images and further classified using supervised classification method to detect the states and stages of land cover changes in research area. The second analysis is of AW detection using originally developed GEOBIA approach. In this analysis, image semantic for AW in the Sebubus Forest were developed based on collected information regarding local knowledge on how people construct AW in the tropical peatlands in the region. Based on the semantic, digitization was conducted per available image of GEHRI in the specified location. Using the two RS techniques, states and stages of biophysical degradation of Sebubus Forest are successfully clarified. This chapter in principle is parts of two publications (Muriadi and Wanglin Yan 2016; Arip and Wanglin 2019)

Chapter 5 discusses the PAD component of the proposed model. Firstly, development of the RTBM is presented. the RT is seperated as point (landmark, centroid), line (rivers, roads), area (boundary) before georegistered as a new base map. Further, a data model is developed to build the RTBM before using it as a geocoding tool. After an accuracy assessment, it was found that the procedure can improve the base map accuracy from 49 percent as of direct digitization to be 75 percent.. Further, linkability of the PAD to the RTBM is assessed based on more than 1.3 million rows of records from four unaggregated databases. The results found the linkability averagely reached 94.63 percent which means high usability of the RTBM and PAD for spatial monitoring purposes. Finally, in this chapter, the grand model of monitoring were applied. Results from chapter 4 were overlaid with PAD analysis to figure out the connection between states and stages of biophysical degradation of peatland with the human social states. Overall, the analysis found that the states and stages of biophysical degradation were in line with some demographic phenomena as scrutinized using developed model. This chapter in principle is part of one published journal paper (Arip, Wanglin, and Hirose 2019)

Chapter 6 highlights the application of the proposed model as implemented in the case study. The relationship between the results of each analysis components is discussed. This chapter also summarizes the results of the chapter 3, 4, 5, and 6. Lessons learned from the development of model and the implementation are highlighted. Prospective use of the proposed model and its components, both in the wider tropical peatland monitoring and its wider application are presented in this chapter. Limitation of the study and the model is also highlighted.

Chapter 7 concludes the whole discussion of the study.

In summary, this dissertation presents an original works for an integrative tropical peatland monitoring in which biophysical aspects and human factors behind the deforestation are assessed through RS images and PAD analysis. While, RS analysis successfully clarify the states and stages of the deforestation, PAD are used for retrieving the involvements of communities. The integrative approach is a systematic understanding of the deforestation in the tropical peatland in wich AW found playing a key role in the progress. It also successfully detected the AW in place and trace out the possible social entities involved in the development. Key components of the integrative approach are the GEOBIA and RTBM as a geocoding tool. Limitation of this study is that it is

tested in one case study only, therefore, some modification is certainly needed for wider use in vast tropical peatland area. However, the core components and main ideas should remain applicable. Finally, it can be concluded that the framework and methods can enrich existing literature as well as contribute to the improvement of current tropical peatland conservation in Indonesia.Practically it can used to stop new projects of AW development in the tropical forest. More over, the procedure of RTBM Development could be a model for developing a new layer of Indonesia NSDI. While, the data sources of this thesis is prevalent and accessible for local governments in Indonesia, it can be used to enhance policy recommendation for specific target of poor RT for effective and efficient social development policy.

Keywords: Tropical Peatland, Remote Sensing, Public Administrative Data, Deforestation.